facts and observations the arguments adduced in its support. He endeavours, from a review of the circumstances under which the veins are placed, to show the inconclusiveness of the objections which have been urged by various physiologists against his and the late Sir David Barry's theory of suction: namely, that the sides of a pliant vessel, when a force of suction is applied, will collapse and arrest the further transmission of fluid though that channel. The considerations which he deems adequate to give efficacy to the power of suction in the veins of a living animal are, first, the position of the veins by which, though pliant vessels, they acquire in some degree the properties of rigid tubes; secondly, the immersion of the venous blood in a medium of a specific gravity at least equal to its own; thirdly, the constant introduction of recrementitious matter into the venous system at its capillary extremities by which the volume of the venous blood is increased, and its motion urged onwards to the heart in distended vessels; and lastly, the gravity of the fluid itself, creating an outward pressure at all parts of the veins below the highest level of the venous system. The author illustrates his positions by the different quantities of blood which are found to flow from the divided vessels of an ox, according to the different modes in which the animal is slaughtered.

The reading of a paper, entitled, "Account of Experiments on Iron-built Ships, instituted for the purpose of discovering a Correction for the Deviation of the Compass produced by the Iron of the Ships." By George Biddell Airy, Esq., A.M., F.R.S., Astronomer Royal, was also resumed and concluded.

In this paper the problem of the deviation of a ship's compass, arising from the influence of the iron in the ship, more particularly in iron-built ships, is fully investigated; and the principles on which the correction for this deviation depends having been determined, practical methods for neutralizing the deviating forces are deduced and illustrated by experimental application. The author states that, for the purpose of ascertaining the laws of the deviation of the compass in the iron-built steam-ship the Rainbow, four stations were selected in that vessel, about four feet above the deck, and at these the deviations of the horizontal compasses were determined in the various positions of the ship's head. All these stations were in the vertical plane, passing through the ship's keel, three being in the after part of the ship and one near the bow. Observations were also made for determining the horizontal intensity at each of the stations. The deviations of dipping needles at three of these stations were also determined, when the plane of vibration coincided with that of the ship's keel, and also when at right angles to it.

After describing the particular method of observing rendered necessary by the nature of the vessel and the circumstances of her position, the author gives the disturbance of the horizontal compass at the four stations deduced from the observations. The most striking features in these results are, the very great apparent change in the direction of the ship's head, as indicated by the compass nearest

the stern, corresponding to a small real change in one particular position, the former change being 97°, whereas the latter was only 23°, and the small amount of disturbance indicated by the compass near the bow.

After giving the observations for the determination of the influence of the ship on the horizontal intensity of a needle suspended at each of the stations, in four different positions of the ship's head, and the disturbances of the dipping needle at three of these stations, the author enters upon the theoretical investigation.

The fundamental supposition of the theory of induced magnetism, on which Mr. Airy states his calculations to rest, is, that, by the action of terrestrial magnetism, every particle of iron is converted into a magnet, whose direction is parallel to that of the dipping needle, and whose intensity is proportional to that of terrestrial magnetism, the upper end having the property of attracting the north end of the needle, and the lower end that of repelling it.

The attractive and repulsive forces of a particle on the north end of the needle, in the directions of rectangular axes towards north, towards east, and vertically downwards, and of which the compass is taken as the origin, are first determined on this supposition in terms of the co-ordinates; and thence the true disturbing forces of the particle in these directions. The disturbing forces produced by the whole of the iron of the ship are the sums of the expressions for every particle. Expressing this summation by the letter S, and transforming the rectangular into polar co-ordinates, Mr. Airy gives to the expressions for the disturbing forces the simplifications which they admit of, on the supposition that the compass is in the vertical plane passing through the ship's keel, and that the iron is symmetrically disposed on both sides of that plane. He thus deduces for the disturbing forces acting on the north or marked end of the needle,

$- \mathrm{I} \cos \delta . \mathrm{M} + \mathrm{I} \cos \delta . \mathrm{P} \cos 2 \mathrm{A} + \mathrm{I} \sin \delta . \mathrm{N} \cos \mathrm{A}$, towards the magnetic north;

$\mathrm{I} \cos \delta . \mathrm{P} \sin 2 \mathrm{A} + \mathrm{I} \sin \delta . \mathrm{N} \sin \mathrm{A}$, towards magnetic east;

$- \mathrm{I} \sin \delta . \mathrm{Q} + \mathrm{I} \cos \delta . \mathrm{N} \cos \mathrm{A}$, vertically downwards:

Where I represents the intensity of terrestrial magnetism; $\delta$ the dip; A the azimuth of the ship's head; and M, N, P, Q, constants depending solely on the construction of the ship, and not changing with any variations of terrestrial localities or magnetic dip or intensity.

From the consideration of these expressions for the disturbing forces is deduced the following simple rule for the correction of a compass disturbed by the induced magnetism only of the iron in a ship.

1. Determine the position of Barlow's plate with regard to the compass, which will produce the same effect as the iron in the ship.

2. Fix Barlow's plate at the distance and depression determined by the last experiment, but in the opposite azimuth.

3. Mount another mass of iron at the same level as the compass, but on the starboard or larboard side, and determine its position so

that the compass points correctly when the ship's head is N.E., S.E., S.W. or N.W.; then the compass will be correct in all positions of the ship's head, and in all magnetic latitudes.

When the disturbing iron of the ship is at the same level as the compass, the correction is stated to be much more simple, it being then only necessary to introduce a single mass of iron at the starboard or larboard side, and at the same level as the compass.

It is farther remarked that if one mass of iron is placed exactly opposite another equal mass, both in azimuth and in elevation, it doubles its disturbing effect: if one mass be placed opposite the other in azimuth, but with elevation instead of depression, or *vice versâ*, it destroys that term of the disturbance which depends on sin A, and doubles that which depends on sin 2 A: and if one mass be placed at the same level as the compass, its effects may be destroyed by placing another mass at the same level, in an azimuth differing 90° on either side. If a disturbance, from whatever cause arising, follow the law of + sin 2 A, (changing sign in the successive quadrants, and positive when the ship's head is between N. and E.), it may be destroyed by placing a mass of iron on the starboard or larboard side at the same level as the compass; if it follow the law of − sin 2 A, the mass of iron must be on the fore or aft side.

From the consideration of the expression for the disturbing forces produced by the ship, it is farther inferred, that both in the construction of the ship and in the fixing of correctors, no large mass of iron should be placed below the compass.

The expressions for the disturbing forces towards north and east, being transformed into forces towards the ship's head and towards the starboard side, give

$I \cos \delta . (-M + P) \cos A + I \sin \delta . N$, for the former, and

$I \cos \delta . (M + P)$, for the latter.

The author next proceeds to investigate the effects which result from the combination of induced magnetism with permanent magnetism. Calling H, S and V the new forces arising from the latter, and directed towards the ship's head, its starboard side, and vertically downwards, the whole disturbing force towards the ship's head becomes

$$H + I \cos \delta . (-M + P) \cos A + I \sin \delta . N;$$

and the whole disturbing force towards the starboard side,

$$S + I \cos \delta . (M + P) \sin A.$$

The manner in which the numerical values of these quantities may be found from experiment is then pointed out, and being determined from the observations on board the Rainbow, at Station I., a comparison is made between the observed disturbances of the needles, and those which would result from the action of the ship as a permanent magnet. From this comparison it appears that almost the whole disturbance is accounted for by the permanent magnetism, and that the residual part follows with sufficient approximation the law of changing signs at the successive quadrants. For the complete verification of the theory it remained only to effect an actual correction of the compass. This was done by placing below the compass, in a

position determined by the previously-ascertained numerical values, a large bar magnet to neutralize the effects of the permanent magnetism of the ship, and a roll of soft iron on one side of the compass to counteract the disturbance arising from induced magnetism. That this correction was effective appears from the very small amount of uncorrected disturbance then observed in the compass.

The observations of the compasses at stations II., III., IV., are similarly discussed: the disturbing force arising from the permanent magnetism of the ship being in like manner determined, a comparison is instituted between the observed and computed disturbance of the compass; and the results of this comparison, with the exception of the observations at Station IV., are found to be in perfect accordance with the theory. Attempts are made to correct the compasses at these stations in the same manner as at Station I., but owing to the imperfection of the compasses they did not succeed so perfectly.

The observations made with the dipping needle are next discussed, and the values of the constants are deduced from them. The general agreement of those determined from the observations when the needle vibrated in the direction of the ship's keel, with those deduced from the observations when the needle vibrated transversely, is pointed out, and is considered an additional proof of the general correctness of the theory.

Observations on the disturbance of the compass in the iron-built sailing-ship Ironsides are next described. These are similar to those in the Rainbow, but not so extensive; and they are discussed on the same principles. From this discussion it is considered that the theory is in perfect accordance with the facts observed both with regard to the deviations and the intensities. The correction of one compass was effected by a tentative process, which the author considers likely to be of the highest value in the correction of the compasses of iron-ships in general. The ship's head being placed exactly north, as ascertained by a shore compass, a magnet was placed upon the beam from which the compass was suspended, with the direction of its length exactly transverse to the ship's keel: it was moved upon the beam to various distances till the compass pointed correctly, and then it was fixed. Then the ship's head was placed exactly east, and another magnet, with its length parallel to the ship's keel, was placed upon the same beam, and moved to different distances till the compass pointed correctly, and then it was fixed. The correction for induced magnetism was neglected, but there would have been no difficulty in adjusting it by the same process, placing the vessel's head in azimuth 45° or 135° or 225° or 315°.

In conclusion Mr. Airy makes the following remarks:—

The deviations of the compass at four stations in the Rainbow, and at two stations in the Ironsides, are caused by two modifications of magnetic power; the one being the independent magnetism of the ship, which retains, in all positions of the ship, the same magnitude and the same direction relatively to the ship; the other being the induced magnetism, of which the force varies in magnitude and direction when the ship's position is changed. In the instances

mentioned, the effect of the former force was found greatly to exceed that of the latter.

It appears that experiments and observations similar to those applied in the above cases are sufficient to obtain with accuracy the constants on which at any one place the ship's action on the horizontal needle depends, namely

$$\frac{H}{I \cos \delta} + \tan \delta . N, \ \frac{S}{I \cos \delta}, \ M, \text{ and } P;$$

and that by placing a magnet so that its action shall take place in a direction opposite to that which the investigations show to be the direction of the ship's independent magnetic action, and at such a distance that its effect is equal to that of the ship's independent magnetism, and by counteracting the effect of the induced magnetism by means of the induced magnetism of another mass, according to rules which are given, the compass may be made to point exactly as if it were free from disturbance.

It appears also, that by an easy tentative method, the compass may now be corrected without the labour of any numerical investigations or any experiments except those of merely making the trials. Although the uniformity of the induced magnetism under similar circumstances is to be presumed, yet the invariability of the independent magnetism during the course of many years is by no means certain.

These statements suggest the following as rules which it is desirable to observe in the present infancy of iron-ship building. It appears desirable that

1. Every iron sea-going ship should be examined by a competent person for the accurate determination of the four constants abovementioned for each of the compasses of the ship, and a careful record of these determinations should be preserved as a magnetic register of the ship.

2. The same person should be employed to examine the vessel at different times, with the view of ascertaining whether either of the constants changes in the course of time.

3. In the case of vessels going to different magnetic latitudes, the same person should make arrangements for the examination of the compasses in other places with a view to the determination of the constant N.

4. The same person should examine and register the general construction of the ship, the position and circumstances of her building, &c., with a view to ascertain how far the values of the magnetic constants depend on these circumstances, and in particular to ascertain their connexion with the value of the prejudicial constant M.

5. The same person should see to the proper application of the correctors and the proper measures for preserving the permanency of their magnetism.

The most remarkable result in a scientific view from the experiments detailed in the present paper is, the great intensity of the permanent magnetism of the malleable iron of which the ship is composed.